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Original Article

STUDY OF SOME PHYSICO-CHEMICAL PROPERTIES OF SWEET CORN

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ABSTRACT

Sweet corn, Zea mays var Rugosa, a member of the Graminaeae is an annual grass. Sweet corn is picked when immature (milk stage) and prepared and eaten as a vegetable, rather than a grain, which are harvested when the kernels are dry and mature (dent stage). Since the process of maturation involves converting sugar to starch, sweet corn stores poorly and must be eaten fresh, canned or frozen, before the kernels become tough and starchy. Hence, Physical properties plays prominent role in designing post harvest/processing equipments while chemical compositions in value additions and processing of various products. In this study some physical properties and chemical compositions of sweet corn were determined. The physical properties of sweet corn determined the average length, diameter and unit weight were 237.5 ± 17.0 mm, 55.62 ± 3.42 mm and 361.26 ± 34.24 g respectively. The bulk density of sweet corn is 1150.55 ± 0.58 kg/m^3, the ear to kernel ratio from 2.3: 1 and the colour L^* a^* b^* of sweet corn was measured to be respectively 74.74 ± 2.8, 0.78 ± 0.78, 49.18 ± 1.54. The chemical properties such as mean moisture content of sweet corn on wet basis were found to be 76.14 ± 0.78 %. The mean value of crude protein content of sweet corn was found to be 9.7 ± 0.472%. The mean value of crude fibre content of sweet corn was estimated to be 1.8 ± 0.1% and the mean value of ash content of was 3.4 ± 0.1%. The total sugar content of sweet corn was found to be 37.5 ± 0.5 in which the reducing sugar content was 2.8 ± 0.05% and non-reducing sugar content of sweet corn was 34.7 ± 0.3%. The starch content of sweet corn was determined to be 14.62 ± 0.4

KEYWORDS: Sweet Corn, Physico-Chemical Property, Controlled Atmosphere, Respiration Rate & Starch

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INTRODUCTION

Corn ranks among the most essential crops in the world agricultural economy. It is recognized as the most efficient converter of the sun's energy into food. The United States is the largest corn-producing country, followed by China, Brazil, Russia, Mexico and India (Food Encyclopedia, 1996). Sweet corn, *Zea mays* var Rugosa, is a member of the Graminaeae is an annual grass which can grow up to 4 meters in height. Sweet corn has a sweeter taste than other corns since the endosperm contains more sugar along with starch (Salunkhe, 1984). Sweet corn is distinguished from other corns by its high sugar content during the milky and early dough stages and kernels are wrinkled and translucent when dry.

Proper understanding of physico-chemical properties gives an effective and proper design of machines and processes for harvesting, handling and storage of agricultural materials and for converting these materials into food. These properties include the size, shape, mass, volume, sphericity, bulk density, true density, porosity, geometric mean diameter, projected area, surface area, radius of curvature, etc. some of the properties such as physicalogical loss in weight, colour evaluation and respiration rate plays vital role in understanding the adaptation

of proper preservation method till they reach the consumers.

Sweet corn is not stored to any great extent. However, it can be stored at 0°C and 90-98% relative humidity for a week or more, if precooled immediately after harvesting. Ryall and Lipton (1972) also stated that to maintain the best qualities, sweet corn must be cooled to as near 0°C as soon as possible after harvest. Time is critical importance because sucrose rapidly changes to starch after harvesting. Sweet corn must also be kept as close to 0°C as feasible at wholesale and retail market. The storage life of sweet corn is very limited because sweetness and tenderness are lost rapidly. Corn will have satisfactory culinary quality for a maximum of 6-8 days at 0°C, 3-4 days at 5°C and 2 days at 10°C. Pantastico *et al.* (1975) recommended temperatures of 0°C and 0-2°C for storage of sweet corn for 1-1.5 weeks at 90-95% relative humidity. Wills *et al.* (1989) stated that sweet corn stored well for 1-2 weeks at 4°C. Now-a-days there is increased acceptance and demand for fresh-cut fruits and vegetables (sometimes called minimally processed or ready-to-eat produce) for many reasons such as their convenience, perceived high nutritional values and freshness.

However, there are two most demanding aspect of all kind of unit operation is the shelling of corn to extract the kernel, which is still carried out by hand, to remove outer sheath and further by shelling the cob traditionally and other is storing of sweet corn, since sweet corn tends to dry out rapidly which adversely affects the texture and flavour.

But there is paucity of information on the physical properties of sweet corn. These properties therefore needed to be investigated and utilized in design of various post-harvest systems. Therefore the objective of this study were to investigate the physico-chemical properties such as length, diameter, bulk density, unit weight, ear-to-kernel ratio, physiological loss in weight, colour evaluation and respiration rate.

MATERIALS AND METHODS

The physico-chemical properties were studied for sweet corn cob and kernels. The quality parameters *viz*., colour, respiration rate and starch content were used for the study.

Physical Properties

For determining the physical properties of sweet corn, the standard procedures suggested by Mohsenin (1986) were followed. The sheath of fresh cobs were removed before measuring physical properties. The details of properties determined and the methods followed are described below.

Length

Length of ten randomly selected sweet corn cobs were measured with the help of scale and the mean length was computed.

Diameter

A Digital Vernier Caliper having a least count of 0.01 mm was used to find the diameter of sweet corn. Ten cobs of sweet corn were randomly selected for measurement. The diameter was measured at three places of each cob and the readings were tabulated to calculate the mean value.

Bulk Density

A perfect rectangular wooden box was taken and its volume was determined by multiplying length, width and height (l x b x h) and then the box was completely filled with sweet corn. The weight of the cobs required to fill the box

was recorded and the bulk density was determined using the following relationship:

$$\text{Bulk Density (kg / m}^3\text{)} = \frac{\text{Weight of cobs (kg)}}{\text{Volume of wooden box (m}^3\text{)}}$$

Unit Weight

Randomly selected ten sweet corn cobs were weighed with the help of an electronic balance and the mean weight was computed and recorded as the unit weight of the sweet corn cob.

Ear-To-Kernel Ratio

Randomly selected ten sweet corn cobs were taken and their whole weights were recorded. Then, the kernels were separated from each cob and the weight of kernels was again measured. From the two weights, ear-to-kernel ratio was computed.

Physiological Loss in Weight (PLW)

For determining physiological loss in weight (PLW), the weight of sweet corn cobs with package was recorded using an electronic balance at periodic intervals (daily). The PLW of cobs was computed from the difference in weight from first day to the subsequent day. The PLW was expressed in per cent either on daily or on cumulative basis from one period to the other. Physiological loss in fruit weight was calculated using the formula:

$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{Weight after storage}}{\text{Initial weight}} \times 100$$

Colour Evaluation

The colour of sweet corn was measured using Minolta Chroma Meter (Minolta Co., Japan: CR200b) (Plate 3.1). It is a light weight, compact tristimulus colour analyzer for measuring reflected light colour. It combines advanced electronic and optical technology in hand held unit that provides high accuracy and complete portability. Using an 8 mm measuring area, diffused illumination and 0° viewing angle, the chroma meter takes accurate colour measurements of a wide variety of subjects quickly and easily.

A pulsed xenon arc (PXA) lamp in a mixing chamber provides diffuse, even lighting over the sample surface. Six high sensitivity silicon photocells, filtered to match the CIE (Commission International d'Eclairage) Standard Observer response are used by the meter's double-feedback system to measure both incident and reflected light. The chroma meter thus detects any slight variation in the spectral power distribution of the PXA lamp and compensates automatically. Chromaticity might be measured in either Yxy (CIE 1931) or $L^* a^* b^*$ (CIE 1976) coordinates and the colour difference could be in terms of (ΔL^*, Δa^*, Δb^*) or ΔE^*ab. Data can be converted between coordinate system or between chromaticity and colour measuring modes by the meter. The CR-200b also offers a choice of either CIE illuminate C or D_{65} lighting conditions and in the present experiment, the CIE illuminate was used.

The colour of corn kernel was recorded by placing the measuring head directly on the kernel. To account for the variation in surface pigmentation, five readings were taken on the cob at different places and the values were averaged. Prior to measurement, the instrument was calibrated with a white standard tile (Y=94.4, x=0.313, y=0.320).

Determination of Respiration Rate

The uniform sized sweet corns harvested on the day of experimentation were used for the respiration study. The respiration rates of the cobs were measured at five different temperatures (ambient (30°C), 20, 10, 5 and 0°C). Sweet corn cobs with and without sheath were enclosed in glass jars of 2000 ml capacity and sealed airtight for 2-6 h depending up on the temperature to allow them to respire. The head space gas composition i.e.O_2 and CO_2 concentrations inside the jars was measured using O_2 - CO_2 Analyzer (make: PBI Dansensor, Denmark) and then the sweet corns were removed from the jars and kept in respective storage environments. Respiration rate of the cobs was recorded daily both under ambient condition (30°C) as well as at four other selected temperatures till end of shelf life of corns. Respiration rate of the cobs was then calculated by using the following formula:

$$\text{Respiration Rate} = \frac{\text{Change in } CO_2 \text{ concentration in headspace x Free volume (ml)}}{\{\text{ml } CO_2/\ (\text{kg} - \text{h})\}\ [[\text{Fruit mass (kg)}] \text{ x } [(\text{Duration of respiration) (h)}]}$$

Where,

Free Volume = (Container Volume - Fruit Volume)

Biochemical Property

Determination of Moisture Content

Moisture content of sweet corn was determined by convection oven drying method (Hall, 1957). Three samples of sweet corn weighing 8-10 g were used to determine the moisture content. The fresh samples were taken in preweighed noncorrosive stainless steel boxes, weighed and placed in a hot air oven maintained at 105 ± 2°C for 24 h. After taking out from oven, the samples were cooled in desiccator and weighed. The samples were again kept in oven for 2 h, cooled and weighed. Heating, cooling and weighing of the samples was repeated till constant weight of sample was attained. The average moisture content of the samples was calculated using the following formula:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1 - W_0}$$

Where,

W_0 = Weight of empty stainless steel box

W_1 = Weight of stainless steel box containing fresh sample before drying

W_2 = Weight of stainless steel box containing sample complete drying

Total Sugar (%)

Reducing sugar content was estimated by Dinitrosalicylic acid (DNS) method described by Sadasivam and Manickam (1992). About 100 mg of powdered dry sample was taken in test tube. The sample was hydrolysed with 5 ml of 2.5N HCl for 3 h by keeping in boiling water bath. Then the contents were cooled and neutralized with solid sodium carbonate until the effervescence ceased. Volume of this digest was made up to 100 ml with water in a volumetric flask and was filtered using Whatman filter paper. Working standards of 0.2, 0.4, 0.6, 0.8 and 1 ml were transferred into a series

of test-tubes. 0.1 and 0.2 ml of the diluted digest were also taken in separate test-tubes and the volume was made up to 1 ml with water. Blank was set with 1 ml of water. To the test-tubes 4 ml of Anthrone reagent was added, the contents were mixed well and kept in boiling water bath for 8 min. Then the content of test-tube was cooled rapidly in cold water and the green color developed was measured at 630 nm using colorimeter. Standard curve was drawn by plotting optical density against concentration of glucose. The amount of total sugars present in the sample was calculated using the following formula:

$$\text{Total sugar} = \frac{\text{Glucose content of sample as obtained from standard graph}}{\text{Aliquot taken for estimation}} \times 100 \times \frac{100}{\text{weight of Sample}} \times \frac{1}{1000}$$

Estimation of Reducing Sugar

Reducing sugar content was estimated by Dinitrosalicylic acid (DNS) method described by Sadasivam and Manickam (1992). About 100 mg of the sample was taken in a test tube and extracted with 5 ml of 80% ethanol twice. The supernatants were pooled in a test tube and evaporated over water bath at 80°C. To the residue, 10 ml of water was added to dissolve the sugars. From this solution, 0.1 and 0.2 ml were transferred to two separate test tubes and the volume was made up to 3 ml with water. Then 3 ml of DNS reagent was added to each test tube and the contents were heated using water bath for 5 min. To the contents of test tube, 1 ml of 40% Rochelle salt solution was added, cooled and the intensity of the color was measured at 510 nm. A series of standard glucose solutions were treated with DNS reagent as described earlier for the test sample and the standard curve was plotted. Reducing sugar content of the sample was calculated using the following equation:

$$\text{Reducing sugar [\%]} = \frac{\text{Sugar content from graph x 10 x 100 x 1}}{\text{Aliquot taken for estimation x Weight of sample} \times 1000}$$

Estimation of Starch Content

Starch content of sweet corn samples was estimated by Anthrone method described by Sadasivam and Manickam (1992). About 0.1 g of powdered sweet corn sample was homogenized in hot 80% ethanol to remove sugars. Then it was filtered and the residue was washed with hot 80% ethanol till it was free from soluble sugars and then transferred into a test tube. The sugar free residue was dried over a water bath. About 5 ml of water and 6.5 ml of perchloric acid were added to the residue, kept at 0°C for 20 min and filtered. The residue was again treated with another portion of 6.5 ml perchloric acid as before and filtered. The supernatants were pooled and the volume was made up to 250 ml. From this diluted solution, were 0.1 and 0.2 ml samples were taken in test tubes, the volume was made up to 1 ml with distilled water to each test-tube, 4 ml of Anthrone reagent was added and heated for about 8 min in boiling water bath. The test tubes were cooled and optical density of the reaction mixture was measured at 630 nm. A series of standard glucose solutions (0 to 500 µg) were treated similarly and optical density was recorded to draw the standard curve. The glucose content of the test sample was found using the standard graph and was multiplied by 0.9 to get starch content.

Calculation

$$\text{Glucose content (\%)} = \frac{\text{Concentration of glucose from graph}}{\text{Aliquot taken for estimation}} \times 250 \times \frac{100}{\text{Weight of Sample}} \times \frac{1}{10^6}$$

Starch Content (%) = Glucose content (%) x 0.9

Estimation of Crude Fibre

The fibre content of sweet corn grains was estimated using the procedure described in AOAC (1960). About 2-5 g of moisture and fat free sample was weighed into 500 ml beaker and to this 200 ml of boiling 0.255 N (1.25% W/V) sulphuric acid and few glass beads were added. The mixture was boiled for 30 min and during boiling, the volume was maintained constant by the adding distilled water at frequent intervals. At the end of 30 min, the mixture was filtered through a muslin cloth and the residue was washed with hot water until it was free from acid. The material was then transferred to the same beaker and 200 ml of boiling 0.313 N NaOH (1.25% W/V) was added. After boiling for 30 min, maintaining volume by frequent addition of water, the mixture was again filtered. The residue was washed repeatedly with hot water till it was free from alkali followed by washing with alcohol and ether. The residue was transferred to a pre-weighed clean and dry crucible, dried over night at 80-100°C in an oven, cooled and weighed (W_1 g). The crucible was then transferred to a muffle furnace and ignited at 550°C for 2-3 h. It was then cooled and weighed (W_2). The difference in weight (W_1-W_2) represented the weight of crude fiber.

$$\text{Crude fiber content (\%)} = \frac{[100-(\text{Moisture + Fat})] \times W_1-W_2}{\text{Weight of sample (Moisture \& Fat free)}}$$

Estimation of Ash

The ash content of sweet corn grains was estimated using the procedure described in AOAC (1960). About 2 g of sweet corn sample was weighed accurately into a porcelain crucible. It was then placed on a clay pipe triangle and heated over low flame till all the material was completely charred. The crucible was later ignited in a muffle furnace at 550°C for 3-4 h, cooled in a desiccator and weighed. The crucible was again heated for about 1 h in the muffle furnace at 550°C as before, till two consecutive weights were almost identical.

Calculation

$$\text{Ash content (\%)} = \frac{\text{Weight of ash x100}}{\text{Weight of sample}}$$

Estimation of Crude Protein

The protein content of the sweet corn grain was determined by Micro Kjeldhal method described by Ranganna (1995). The procedure consists of 2 steps: a. Digestion : A known weight of sample (0.1g) was taken in a micro kjeldahl flask, a pinch of digestion mixture and 2 ml of concentrated sulphuric acid were added to it. The mixture was heated for about 2.5-3 h till a clean greenish solution was formed. A blank was also kept for digestion without sample. b. Distillation and titration: The digest was transferred to the Paras Wagner distillation unit, the micro kjeldahl flask was washed with little quantity of water and the washings were also transferred to the distillation unit. To this, 10 ml of 40% NaOH was added and the contents were steam distilled. The liberated ammonia was collected in 25 ml of 2% boric acid containing few drops of mixed indicator. The boric acid solution containing ammonia was titrated against standard acid (0.05 N H_2SO_4), similarly blank titre value was determined blank digest and the amount of nitrogen there by the amount of crude protein in the sample was calculated using the following equation:

Calculations

$$\text{Crude protein (\%)} = \frac{(A-B) \times 0.05 \times 14 \times 100 \times 6.25}{W}$$

Where, A = Titre value for sample

B = Titre value for blank

W = Weight of sample taken

RESULTS AND DISCUSSIONS

Physical Properties

The physical properties of sweet corn cob are presented in Table 1. The average length of sweet corn was found to be 237.5 ± 17.0 mm. The mean diameter of sweet corn was measured to be 55.62 ± 3.42 mm. The unit weight of the sweet corn was recorded as 361.26 ± 34.24 g. The mean bulk density of sweet corn was found to be 1150.55 ± 0.298 kg/m^3. The ear-to-kernel ratio of sweet corn was computed to be 2.3:1. The colour in terms of tri-stimulus values of L^* a^* b^* of sweet corn was measured to be respectively 74.74 ± 2.8, 0.78 ± 0.78, 49.18 ± 1.54.

Table 1: Some Physical Properties of Sweet Corn

Sl. No.	Parameter	Value
1	Length (mm)	237.5 ± 1.70
2	Diameter (mm)	55.62 ± 3.42
3	Unit weight (g)	361.26 ± 34.24
4	Bulk density (kg/m^3)	1150.55 ± 0.298
5	Ear-to-Kernel Ratio	2.3:1
6	L^* Colour a^* b^*	74.74 ± 2.8 0.78 ± 0.78 49.18 ± 1.54

Biochemical Properties

The biochemical properties of sweet corn are presented in Table 2.The mean moisture content of sweet corn on wet basis was found to be 76.14 ± 0.78 %. The mean value of crude protein content of sweet corn was found to be 9.7 ± 0.472%. The mean value of crude fibre content of sweet corn was estimated to be 1.8 ± 0.1% and the mean value of ash content of was 3.4 ± 0.1%. The total sugar content of sweet corn was found to be 37.5 ± 0.5 in which the reducing sugar content was 2.8 ± 0.05% and non-reducing sugar content of sweet corn was 34.7 ± 0.3%. The starch content of sweet corn was determined to be 14.62 ± 0.4.

Table 2: Chemical Constituents of Sweet Corn

Sl. No.	Parameter	Value
1	Moisture,%	76.14 ± 0.777
2	Crude protein, %	9.7 ± 0.472
3	Crude fibre,%	1.8±0.1
4	Ash, %	3.4 ± 0.1
5	Total sugar, %	37.5 ± 0.5
6	Reducing sugar, %	2.8 ± 0.05
7	Non Reducing sugar, %	34.7 ± 0.3
8	Starch	14.62±0.4

Respiration Studies of Sweet Corn

The results of respiration studies conducted on sweet corn cobs with and without husk at different temperatures are presented below. The results of respiration studies conducted on sweet corn cobs with and without husk at different temperatures are presented below.

The respiratory pattern showed in figure 1 varied physiological response of the cobs towards the modified atmosphere. The respiration peak of sweet corn cob with husk in ambient condition ($30^{\circ}C$) was very high 416.71 ml CO_2 kg^{-1} h^{-1} recorded on third day after harvest. It was 265.47 ml CO_2 kg^{-1} h^{-1} on 4th day of harvest at $20^{\circ}C$, 188.4 ml CO_2 kg^{-1} h^{-1} on 6th day of storage at $10^{\circ}C$, 170.4 ml CO_2 $kg^{-1}h^{-1}$on 8th day of storage at $5^{\circ}C$, whereas at $0^{\circ}C$, it was only 162.1 ml CO_2 kg^{-1} h^{-1} on 11th day of storage. Peak respiration rate of sweet corn cob without husk was 493.47 ml CO_2 kg^{-1} h^{-1} at ambient condition on 3rd day of storage, 378.85 ml CO_2 kg^{-1} h^{-1} at $20^{\circ}C$ on 3rd day of storage, 200.3 ml CO_2 kg^{-1} h^{-1} at $10^{\circ}C$ on 6th day of storage, 188.1 ml CO_2 $kg^{-1}h^{-1}$ at $5^{\circ}C$ on 8th day of storage and 182.9 ml CO_2 kg^{-1} h^{-1} at $0^{\circ}C$ on 9th day of storage. The lower respiration rate observed in sweet corn with and without husk at lower temperatures is in tune with general observation on many fruits and vegetables.

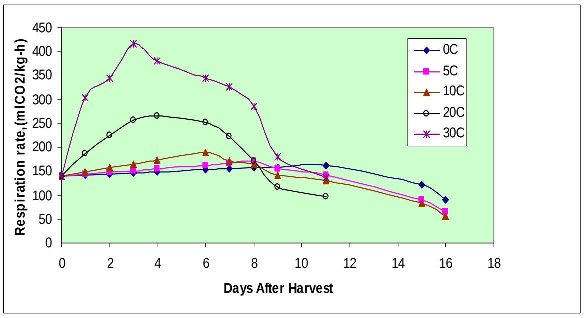

Figure 1: Respiration Characteristics of Sweet Corn with Husk Stored at Five different Temperatures

Also, the peak respiration rates of sweet corn cobs without husk was 493.47 ml CO_2 $kg^{-1}h^{-1}$ at ambient temperature on the 3rd day of storage, 378.85 ml $CO_2kg^{-1}h^{-1}$ at 20^{o} C on the 3rd day of storage, 200.3 ml CO_2 $kg^{-1}h^{-1}$ at 100C on 6th day of storage, 188.1ml $CO_2kg^{-1}h^{-1}$ at 50 ^{o}C on the 8th day of storage and 182.9 ml CO_2 $kg^{-1}h^{-1}$ at 0 ^{o}C on the 9th day of storage (Figure 2).

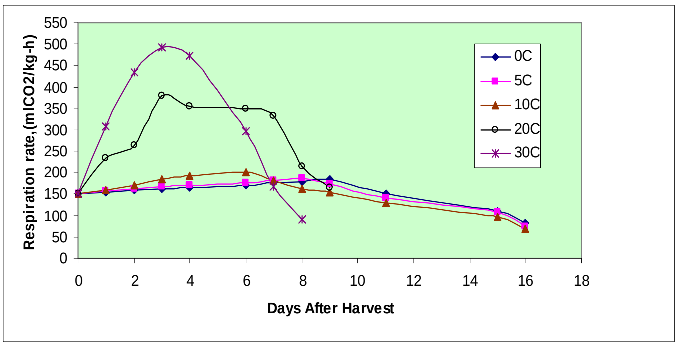

Figure 2: Respiration Characteristics of Sweet Corn without Husk Stored at Five different Temperatures

It could be seen that the lower storage temperature resulted in reduced respiration rate. The respiration rate of a fresh produce is the process of temperature dependent and regulated by many enzymes. In the present study, the low

storage temperature resulted in reduced enzyme activity thus lowering the respiration rate. In conclusion, the initial respiration rate of sweet corn cob with husk (6 hours after harvest) was measured to be 140 ml CO_2 $kg^{-1}h^{-1}$. The peak respiration rates of sweet corn cobs with outer husk intact at 30, 20, 10, 5 and 0^o C temperatures were 416.7, 265.17, 188.4, 170.4 and 162.1 ml CO_2 $kg^{-1}h^{-1}$, on the 3rd, 3rd, 6th, 8th, and 9th day after harvest, respectively. Also, the initial respiration rate of sweet corn cob without husk (6 hours after harvest) was measured to be 150 ml CO_2 $kg^{-1}h^{-1}$.The peak respiration rates at 30, 20, 10, 5 and 0 ^{0}C were 493.4, 378.5, 200.3, 188.1 and 182.9 ml CO_2 $kg^{-1}h^{-1}$ on the 3rd, 4th, 6th, 8th, and 11th day after harvest, respectively.

CONCLUSIONS

Knowledge of some engineering properties, general composition and storage studies of sweet corn cob and sweet corn kernel would enable the food processors to design and develop technology that suits the material exactly, which in turn minimize post harvest loses, and helps in complete utilization of the nutrients present.

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